Vol. XXII. — No. 2. February 1940.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[621. 132.3 (.493)]

Class 12 « Atlantic » locomotives,

Belgian National Railways Company,

by R. NOTESSE,
Mechanical Engineer, Belgian National Railways Company.

The locomotives of moderate power which are used by the Belgian National Railways Company to haul express trains consisting of a few steel coaches, at ever shorter times, are mostly of an out of date type.

The time had come, therefore, to put in hand the construction of a new class of faster locomotive, of moderate weight and as high a specific power as possible. It was a question of improving on the design of similar locomotives from the various points of view of lowering the cost of the useful horse-power/hour, simplicity of maintenance and driving, and minimum capital cost.

For a long time Belgian rolling stock has been so constructed that the static loads of the driving wheels attain the maxima compatible with the rail sections and the track sleepering. Following the example of the United States, since 1910 class 10 *Pacific* locomotives had been put into service, which were considered remarkable at the time. Twenty years later, the new class 1 *Pacific*, with its adhesive weight of 72 t. (70.9 Engl. tons) could easily haul the heaviest high-speed trains at continuous speeds of 120 km. (75 miles) an hour on the level and trains of 500 t. (492 Engl. tons) at a speed of 80 km. (50 miles) an hour on the Luxembourg line which has long 1 in 62 gradients. 35 locomotives of this kind enable all the heavy express trains to be economically worked, but they are too powerful for hauling on the Brussels-Ostend and Brussels-Liége lines trains which only consist of a few coaches.

In view of the traction capacity of a four-coupled locomotive with an adhesive weight of 46 to 48 t. (45.8 to 47.2 Engl. tons), the choice fell on the *Atlantic* type which has less inherent resistance, great running flexibility and which, by the use of an overhanging firebox can be fitted with a very powerful boiler. It was found possible to limit the total weight to two-thirds of that of the class 1 *Pacific*, although the specific power is definitely higher.

The successive improvements carried out on locomotives since about 30 years,

at which time most Belgian express locomotives of average power were built, has always complicated the maintenance and repair of this stock. The question, therefore, arose whether it was desirable to apply all these improvements to the new locomotives with a view to increasing their efficiency as much as possible, or only use simple and tested arrangements, sacrificing progress, which was perhaps hazardous.

A judicious choice governed by the desire for simplicity was made, and it was possible to test a variety of the most interesting new arrangements, as 6 original types were constructed. This was decided upon in order not to increase the cost of the new locomotives unduly on account of drawing-office and tools costs and to take advantage of the lower cost of building a certain number at once. Such a decision permitted new methods to be observed and experience gained, before adoption of a final design.

An engine with more than two cylinders would only be justified :—

(1) If, in order to transmit the desired driving force, the rods, crossheads and pistons would be of unusual proportions the more so as at high angular speeds the large mass of these parts would give rise to prohibitive inertia forces.

(2) If double expansion of steam were considered to be essential, complication of the steam piping, valves and valve gear, and the energy losses to which they give rise, being overlooked.

The question was, however, to design a locomotive which was not subject to hunting and oscillation, a frequent trouble with 2-cylinder engines. With the exception of locomotives with poppet valves or piston valves, in the motion of which it is possible to incorporate counterbalance weights forming an integral part of same, the American practice, which consists of balancing at least 40 per cent of the reciprocating masses, appears to be the only one which enables the disturbing movements of the locomotive to be controlled. It is also necessary that this balancing does not overload the track excessively, especially as the *Atlantic* locomotives have only four wheels to take the balance weights.

This American practice which we have been able to try out when converting locomotives, the disturbing movements of which were very pronounced, has come up to expectations. In order not to exceed the highest dynamic overloads of other locomotives of the Belgian National Railways Co., outside cylinders could not be used. The arrangement of these between the frames reduced by about 3 to 2 the dynamic overloads.

In addition, this interior arrangement of cylinders has the advantage of reducing the air-cooling effect on these parts.

On the other hand, inside cylinders make it necessary to have a crank axle. The great progress made in recent years in the construction of such axles of self-balanced parts has considerably improved their life so that they are no longer, as formerly, a very unfavourable feature.

Finally the inside motion appeared to necessitate the use of eccentrics, suitable for angular speeds of about 400 r.p.m. So as to avoid the use of such details, recourse was had to the fitting of a fly crank at the right and left, which transmits its movements to a transverse transmission shaft, the bearing supports of which were made as rigid as possible.

The choice of a diameter of 480 mm. (18 7/8 in.) for the cylinders (which will be dealt with later), and 2.10 m. (6 ft. 43/64 in.) for the driving wheels, which is the customary maximum on

Belgian locomotives, and also 360 mm. (14 3/16 in.) diameter for the piston valves, has determined the placing of the centre lines in accord with the clearance limits.

In order that the underframe shall have its essential characteristics of resistance to deformation and of rigidity, bar frames were used, as on all recent locomotives of the Belgian National Railways Co. However, the thickness at present is not more than 90 mm (3 17/32 in.) in order not to unduly increase the weight.

A front bogie was necessary for a high-speed locomotive and for standardisation purposes that with a centering device of the constant-resistance type, as fitted to the Class 1 locomotives, was adopted.

Coupled to its tender, the locomotive can work round curves having a minimum radius of 120 m. (6 chains).

The locomotive and tender were equipped with Westinghouse self-regulating brake, the braking coefficient of the coupled wheels and rear carrying pair being 130 %, which coefficient is also adopted for the tender when running at high speeds and fully loaded. The braking coefficient for the bogie is 51 %. In this way it has been possible to maintain the required stopping distances when braking from 140 km. (87 miles) an hour.

There is no doubt that the choice of the boiler pressure of 18 kgr./cm² (256 lb./sq. in.), which is higher than with previous Belgian locomotives, has contributed to the increased efficiency of the latest *Pacific*. In order to confirm the good behaviour in service of the boiler tube nest, it was thought that the new *Atlantic* locomotive should be kept at this increased pressure before adopting that of 20 kgr./cm² (280 lb./sq. in.), the

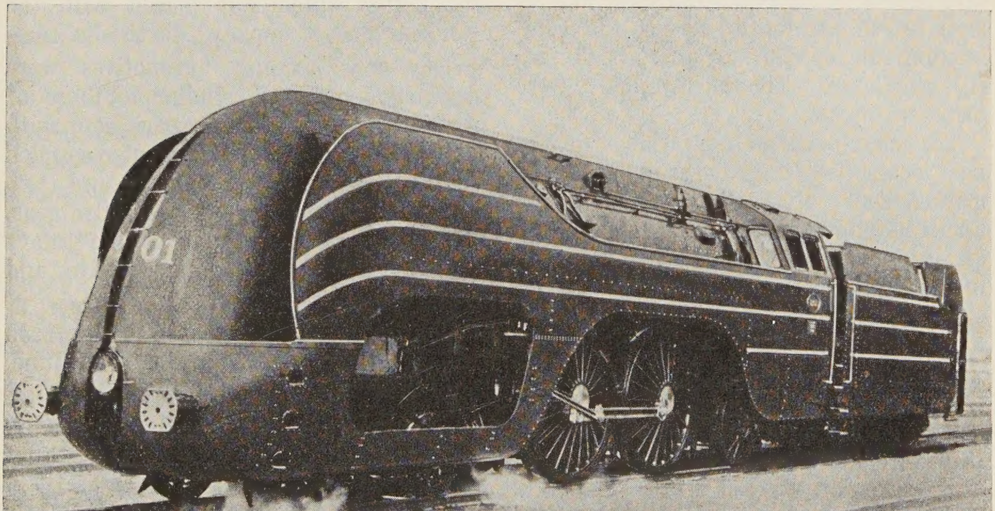
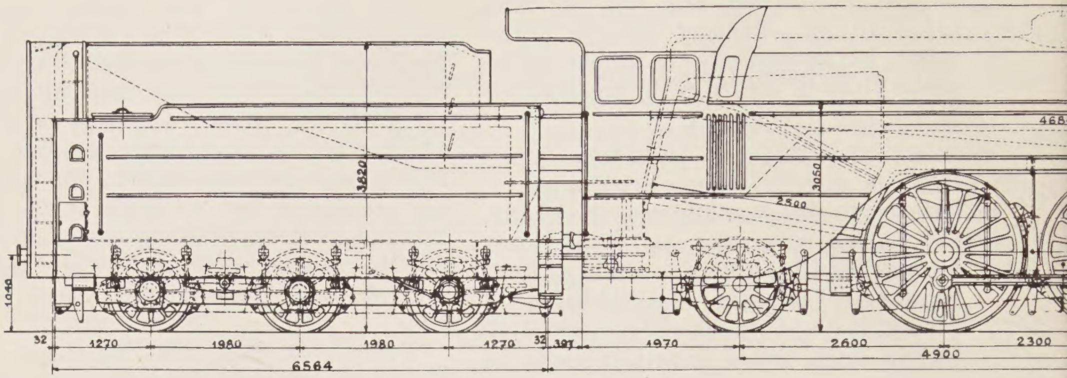


Fig. 1.



maximum generally permitted at the present time.

A type of boiler customary on the Belgian National Railways was used, having a barrel of approximately 1.70 m. (5 ft. 7 in.) diameter and smoke tubes 4.68 m. (15 ft. 49/32 in.) long. With regard to the grate, this was of ample dimensions — 3.70 m² (39.8 sq. ft.) of area — so as not to exceed the combustion rate of 600 kgr./m² (122 lb./sq. ft.) per hour. The barrel plates were made of nickel.

The characteristic appearance of the new locomotives, Fig. 1, results from the arrangement of plating patented by Mr. Huet and consisting in deflecting the air in a suitable manner. This arrangement has the following features :

— A front shield which has a longitudinal specially shaped opening through which a small quantity of air passes, whose purpose is to compensate for the usual depression and create a sort of fluid streamlining;

— Divergent vertical openings arranged laterally where air shocks are likely to be produced;

— Horizontal openings at the front of the cab and of the tender, which tend to create a zone of calm air behind.

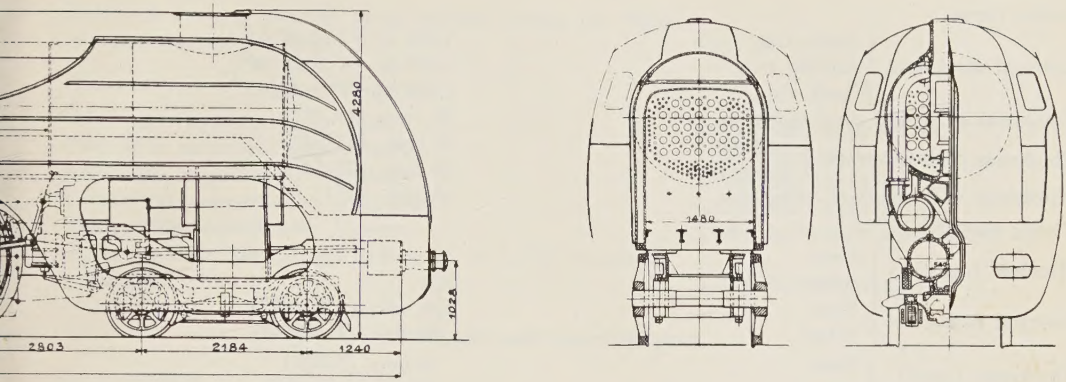
The estimated weight empty was 80 t. (78.7 Engl. tons).

These were the essentials specified by the Belgian National Railways Co. to the builder, with whom it rested to produce the drawings, subject to approval. The construction was entrusted to the « Cockerill » Company, Seraing, except for the boiler which was placed with the « L'Energie » Company, Marcinelle.

The new *Atlantic* locomotives were designated class 12, similar to those of the same type built 50 years ago, with 2.10 m. (6 ft. 43/64 in.) diameter coupled wheels, two inside cylinders, and also including as a variant poppet valve gear. The valve gear now used is the rotary cam gear, Dabeg on one locomotive, and Caprotti on another.

The locomotives numbered 1201 to 1206 were put into service in May and June, 1939.

Six tenders with 6 wheels and having a capacity of 8 tons of fuel and 24 m³ (5 280 Br. gall.) of water, of which there are about 500 on the Belgian National Railways, were made fit for working at high speed. This consisted in providing them with Isothermos axle boxes, self-regulating brake, and also the arrange-



ment of shaped sheets to deviate the air through the diverging openings which have been mentioned. This arrangement gives the rear of the tender the characteristic appearance shown in Fig. 9.

The essential arrangements of the locomotive and tender are shown in the schematic diagram, Fig. 2, and the following table shows the dimensions adopted.

Boiler.

Inside firebox.

Length, inside	top	2.393 m. *(7' 10 13/64")*
	bottom	2.500 m. *(8' 2 7/16")*
Width, inside	top	1.396 m. *(4' 7")*
	bottom	1.480 m. *(4' 10 9/32")*
Internal height above foundation ring	front	1.966 m. *(6' 5 25/64")*
	back	1.479 m. *(4' 10 15/64")*
Inclination of crown		1 in 52
Thickness	of crown and side plates	15 mm. *(19/32")*
	of tubeplate	15 to 28 mm. *(19/32" to 12 7/64")*
Length of arch		1.422 m. *(4' 8")*
Arch tubes	number	3
	internal diam.	67 mm. *(2 41/64")*
	thickness	4.5 mm. *(3/16")*
Volume above grate, minus the brick arch and arch tubes		6 m^3 *(212 cu. ft.)*

Outside firebox.

Distance between top of shell and firebox crown	0.474 m. *(1' 6 43/64")*
Thickness of nickel steel plate	14 mm. *(35/64")*

Grate.

Length	2.500 m. *(8' 2 7/16")*
Width	1.480 m. *(4' 10 9/32")*
Inclination	9° 25'
Proportion of air passages sectional area to grate area	35 %

Boiler barrel.

Internal diameters	front ring	1.640 m. *(5' 4 35/64")*
	middle ring	1.470 m. *(4' 9 55/64")*
	back ring	1.640 m. *(5' 4 35/64")*
Thickness of nickel steel plates		15 mm. *(19/32")*
Thickness of butt straps	external	13 mm. *(33/64")*
	internal	13 mm. *(33/64")*
Thickness of smokebox tubeplate		25 mm. *(1")*

Tubes and flues.

Number (smooth)	flues	33
	tubes	123
Internal diameter	flues	125 mm. *(4 29/32")*
	tubes	45 mm. *(1 49/64")*
Thickness (steel)	flues	4 mm. *(5/32")*
	tubes	2.5 mm. *(3/32")*
Length between tube plates		4.680 m. *(15' 4 9/32")*

Superheater elements.

Internal diameter	28 mm. *(1 7/64")*
Thickness	3.5 mm. *(9/64")*
Distance from the end nearest the firebox	283 mm. *(11 5/32")*

Heating surface.

Direct	firebox (above the grate)	16.50 m² *(177.6 sq. ft.)*
	arch tubes	1.90 m² *(20.5 sq. ft.)*
Indirect	gas side	142.2 m² *(1 530.6 sq. ft.)*
	water side	155.1 m² *(1 669.4 sq. ft.)*
Total (gas side)		160.6 m² *(1 728.7 sq. ft.)*
Superheating surface (external)		63.00 m² *(678.1 sq. ft.)*
Ratio of superheating to heating surfaces		0.392
Evaporative surface of water (stays deducted)		9.92 m² *(106.8 sq. ft.)*
Volume of water [15 cm. (6 in.) above topmost part of firebox]		6.990 m³ *(247 cu. ft.)*
Volume of steam [15 cm. (6 in.) above topmost part of firebox]		2.600 m³ *(92 cu. ft.)*

Smokebox.

Internal length	3.156 m. *(10' 4 9/32")*
Internal diameter	1.670 m. *(5'5 3/4")*
Thickness of wrapper	10 mm. *(25/64")*

Chimney.

Inside diameter of each of the 2 pipes	0.452 m. *(17 25/32")*
Height of chimney top above rail	4.245 m. *(13' 11 1/8")*

Sections of gas passages

Across ashpan damper		0.72 m² *(7.75 sq. ft.)*
Across grate		1.29 m² *(13.9 sq. ft.)*
Across the tubes	flue tubes where most reduced by elements	0.2780 m² *(2.99 sq. ft.)*
	small tubes	0.1956 m² *(2.11 sq. ft.)*
	total	0.4736 m² *(5.10 sq. ft.)*

Ratio of the gas passage cross section across the flues to that across the tubes	1.42

Cross section of steam passages.

With the regulator fully open	2.9053 dm^2 *(45.03 sq. in.)*
Inlet side, saturated steam header	2.5447 dm^2 *(39.44 sq. in.)*
Inlet side, superheater elements	2.3200 dm^2 *(35.96 sq. in.)*
Outlet side, superheater elements	2.3200 dm^2 *(35.96 sq. in.)*
Outlet side, superheater header	5.0894 dm^2 *(78.88 sq. in.)*
Across a main steam pipe (180 mm. = 7 3/32 in. inside diameter)	2.5447 dm^2 *(39.44 sq. in.)*

Frame and running gear.

Main frames.

Length		9.617 m. *(31' 6 5/8")*
Thickness		0.090 m. *(3 9/16")*
Depth in line with cylinders		0.260 m. *(10 1/4")*
Depth of bars above the driving boxes		0.135 m. *(5 5/16")*
Depth between wheels	total	0.694 m. *(2' 3 5/16")*
	top bar	0.135 m. *(5 5/16")*
	bottom bar	0.105 m. *(4 1/8")*
Interior wheel base		1.100 m. *(3' 7 5/16")*
Lateral displacement of the bogie frame in relation to bogie centre line		2 × 105 mm. *(2 × 4 1/8")*

Wheels and axles.

Diameter of wheels measured on the tread (new tyres)		bogie	0.900 m. *(2' 11 1/2")*
		coupled	2.100 m. *(6' 10 9/32")*
		carrying	1.262 m. *(4' 1 43/64")*
Thickness of tyres		bogie wheels	76 mm. *(3")*
		driving and coupled wheels	81 mm. *(3 3/16")*
Thickness of tyre flanges 10 mm. (3/8 in.) from tread		bogie and trailing	32.5 mm. *(1 9/32")*
		front coupled	32.5 mm. *(1 9/32")*
		rear coupled	22 mm. *(7/8")*
Distance between inside faces of tyres			1.360 m. *(4' 5 35/64")*
Journals	Diameters	bogie axles	0.180 m. *(7 3/32")*
		driving and coupled axles (bored to 60 mm. = 2 3/8 in. diam.)	0.245 m. *(9 5/8")*
		rear carrying axle (bored to 100 mm. = 3 15/16 in. diam.)	0.270 m. *(10 5/8")*
	Lengths	bogie axles	0.128 m. *(5 1/64")*
		driving axle	0.250 m. *(9 27/32")*
		coupled axle	0.285 m. *(11 15/64")*
		rear carrying axle	0.375 m. *(14 3/4")*
	Distance from centre to centre	bogie axle	1.016 m. *(3' 4")*
		driving crank axle	1.200 m. *(3' 11 15/64")*
		coupled axle	1.170 m. *(3' 10 5/64")*
		rear carrying axle	1.075 m. *(3' 6 5/16")*

Wheel seats	Diameters	bogie axles	0.178 m. *(7")*
		driving and coupled axles	0.250 m. *(9 27/32")*
		rear carrying axle	0.235 m. *(9 5/32")*
	Lengths	bogie axles	0.182 m. *(7 5/32")*
		driving and coupled axles	0.195 m. *(7 43/64")*
		rear carrying axle	0.175 m. *(6 29/32")*
Crank pins	Diameters	inside driving	0.245 m. *(9 5/8")*
		crank axle coupling rod pin	0.130 m. *(5 1/8")*
		rear coupling	0.130 m. *(5 1/8")*
	Lengths	inside driving	0.170 m. *(6 11/16")*
		crank axle coupling rod pin	0.100 m. *(3 15/16")*
		rear coupling	0.100 m. *(3 15/16")*
	Distances between centres measured across the engine	inside driving	0.530 m. *(1' 8 7/8")*
		coupling	1.953 m. *(6' 4 29/32")*
Springs	Distance betw. centres of spring hangers	bogie	1.016 m. *(3' 4")*
		driving	1.100 m. *(3' 7 5/16")*
		coupled	1.100 m. *(3' 7 5/16")*
		rear carrying	1.100 m. *(3' 7 5/16")*
	Number and section of grooved plates	bogie	18 plates 120 × 13 mm. *(4 23/32" × 33/64")*
		driving	16 plates 90 × 13 mm. *(3 17/32" × 33/64")*
		coupled	16 plates 90 × 13 cm. *(3 17/32" × 33/64")*
		rear carrying	12 plates 120 × 13 cm. *(4 23/32" × 33/64")*
Side play	between lateral face of axle box and coupled wheel boss		2.5 mm. *(3/32")*
	of the coupled boxes in their guides	in the centre	0.5 to 0.6 mm. *(5/256" to 3/128")*
		top and bottom	2 × 2 mm. *(2 × 5/64")*

Motion.

Engine.

Diameter of cylinders		0.480 m. *(18 7/8")*
Piston stroke		0.720 m. *(28 3/8")*
Section of a cylinder steam pipe		0.324 dm^2 *(5.02 sq. in.)*
Clearance volume	front	16.316 dm^3 *(995.7 cu. in.)*
	rear	16.473 dm^3 *(1 005.3 cu. in.)*
Swept volume		130.288 dm^3 *(7 951 cu. in.)*
Ratio $\dfrac{\text{clearance volume}}{\text{swept volume}}$	front	12.51 %
	rear	12.64 %
Inclination of cylinders from horizontal		2.5 %
Length of driving rods		2.620 m. *(8' 7 5/32")*
Ratio $\dfrac{\text{length of driving rod}}{\text{length of crank pin radius}}$		7.28

Valve gear.

Diameter of piston valves	0.360 m. *(14 3/16")*
Maximum travel	0.200 m. *(7 7/8")*
Section of the cylindrical passage of a sleeve	0.1018 m^2 *(157.7 sq. in.)*
Section of a set of ports completely uncovered	0.0372 m^2 *(57.7 sq. in.)*
Section of the passage at the base of the blast pipe	0.091 m^2 *(141 sq. in.)*
Lengths of ports	50 mm. *(1 31/32")*
Admission lead	8.03 mm. *(5/16")*
Steam lap	50 mm. *(1 31/32")*
Exhaust lap	10 mm. *(1 31/32")*

Weight.

Locomotive, empty		81 t. *(79.7 Engl. tons)*
In average working order	1st pair of wheels	12 t. *(11.8 Engl. tons)*
	2nd » »	12.1 t. *(11.9 Engl. tons)*
	3rd » »	23.4 t. *(23.0 Engl. tons)*
	4th » »	22.4 t. *(22.0 Engl. tons)*
	5th » »	19.3 t. *(19.1 Engl. tons)*
	Total	89.2 t. *(87.8 Engl. tons)*
Adhesive weight		45.8 t. *(45.1 Engl. tons)*

Description of principal features.

Boiler.

Inside firebox. — The firebox is large. Its side walls are almost vertical. This makes it easy for the steam to escape from the layers of water. This arrangement has also the advantage that the inside firebox can be removed without having to take down the plates of the outside shell.

The inside firebox and the stays are of copper as in all locomotives of the Belgian National Railways Co. The stays are 27 mm. (1 1/16 in.) diameter and they are spaced about 85 mm. (3 11/32 in.) apart.

The transverse outline given to the upper portion of the inside firebox, whilst enabling large layers of water to be dealt with has allowed the tubeplate to take tubes of satisfactory size, two vertical rows of small tubes being arranged on the left and right of the flue tubes.

The arch is made up of refractory elements simply resting on three arch tubes. It is long and forms a section for the passage of the gases in accordance with recent practice adopted in the United States. This arrangement enables good combustion to take place through strong draught owing to the high efficiency of the blast pipe.

The grate is made up of rocking firebars, the teeth of which over-ride, and includes a drop grate section in front. An arrangement of rocking levers to separate clinkers and to shake out the fine cinders, extends into the cab, for use by the engine men.

Firebox shell. — The outer firebox has a round crown to avoid the use of plates pressed at a sharp angle as used in the Belpaire square type arrangement.

The rigid roof staying consists of 20 rows of nickel steel cross stays, spaced approximately 100 mm. (3 15/16 in.) apart and comprising 12 stays arranged radially. The front articulated staying consists of 2 rows of crown bars of less than half this height, suspended by ho-

rizontal flanges placed edgewise and bent again in front at a right angle so as to be partly supported on the tubeplate, and partly on the two front rows of the largest diameter crown bars.

The wrapper is made in one piece 14 mm. (9/16 in.) thick. It is reinforced on the outside of each corner of the roof by a plate 10 mm. (25/64 in.) thick riveted all round, to obtain the necessary thickness in order to give the crown bars, which are most inclined, hold on a sufficient number of threads. These additional plates are festooned on the edges so as to avoid continuous bending lines.

The staying of the upper portion of the blackplate consists of 12 longitudinal crown bars fixed to the firebox crown. It is reinforced by 4 rolled T section pieces and stiffened transversely by 7 crown bars 42 mm. (1 21/32 in.) diameter.

Both the transverse and vertical crown bars are made of steel having a nickel content of 2 to 3 %, with a minimum tensile strength of 58 kgr./mm^2 (36.8 Engl. tons/sq. in.), and elastic limit of at least 38 kgr./mm^2 (24.1 Engl. tons/sq. in.).

The foundation ring, 80 mm. (3 5/32 in.) wide, is fitted at the bottom of the water spaces and is of a shape particularly favourable to giving off steam.

An automatically locked firebox door hinged horizontally, having an opening of 400 $\times$ 310 mm. (15 3/4 $\times$ 12 3/16 in.), enables firing to be easily carried out.

Boiler barrel. — The barrel is formed of 3 rings of 15 mm. (19/32 in.) plate. The butt straps are the same width, with straight edges. The front and back shell rings fit in the central ring. Although this arrangement has been criticised on grounds of stagnation and deposits, it was chosen because of the reduction in weight in comparison with the usual telescopic arrangement. The rings are rivetted to each other and also to the firebox shell and the front tubeplate by double seams. The 2 to 2.3 % nickel steel, of which the plates are made, gives a minimum breaking strength of 52 kgr./mm^2 (33 tons/sq. in.) and a resiliency of at least 15 kgrm./cm^2. The central ring carries the dome, as this is the best position to lessen priming.

The centre line of the boiler barrel is 3.050 m. (10 ft.) above rail level.

The top of the smokebox tubeplate is stayed by a plate 18 mm. (45/64 in.) thick and 520 mm. (20 1/2 in.) long; this plate is stiffened by gusset plates.

Tubes and superheater elements. — The number, diameter and length of the tubes and flues and also the superheater elements to be arranged therein, have received particular attention.

The amount of heat absorbed by convection, the resistance to the flow of gases in relation to the rubbing surface of the walls and the section of the passages, as well as the degree of superheating are all factors which were considered simultaneously with the problems of production of steam and its exhaust, in order to determine the dimensions to be given to the tubes and superheater (1).

Starting from a usual length of tubes, 4.68 m. (15 ft. 4 9/32 in.), and bearing in mind a volume of water generally admitted in the weight of the locomotive and with a view to the use of Schmidt type superheater elements with double

(1) See A. CHAPELON : « La locomotive à vapeur ». Transmission de la chaleur à l'eau et à la vapeur. — Dr. Ing. U. BARSKE : « Rechnerische Untersuchung der Wärmeübertragung im Lokomotivlangkessel ».

circuit, we were led to select superheater flue tubes 125 × 133 mm. (4 63/64 × 5 15/64 in.) diameter — in order to arrange therein elements 28 × 35 mm. (1 7/64 × 1 3/8 in.) — and small fire tubes 45 × 50 mm. (1 49/64 × 1 31/32 in.).

33 superheater tubes and 123 boiler tubes were arranged at best in the boiler barrel, the average internal diameter of which is 1.64 m. (5 ft. 4 35/64 in.), two kinds of superheater being used :

— the first of the improved Schmidt type, with a header having sections of decreasing size from the admission pipe bringing in the saturated steam, and of increasing size in the superheated steam section towards the delivery pipes;

— the second, known as « Belgian superheater », with two separate vertical headers arranged one behind the other, and straight elements.

The return bends at the firebox end are only 225 mm. (8 29/32 in.) away from the tubeplate. The connections joining the elements to the headers are made by coned or spherical caps on conical bearings. The element fixing bolts are made of semi-hard steel quenched and tempered to avoid their deformation when hot.

The Superheater Company were asked to supply two varieties of superheaters with improved elements called type 5 P 4 and comprising 4 small tubes carrying saturated steam, placed round a large central tube for the return of the superheated steam; owing to the differences in the friction surfaces and gas passage sections they adopted a slightly different division of large and small tubes : 26 in the one case and 141 in the other.

The tubes are reduced respectively to 105 and 36 mm. (4 1/8 and 1 27/64 in.) diameter in accordance with the latest Reichsbahn practice. They are expanded in the firebox tubeplate after having been properly fixed therein.

Smokebox. — The smokebox, of the same inside diameter as the central barrel ring, is of 10 mm. (25/64 in.) plate shrunk on the front portion of the boiler barrel which extends beyond the tubeplate. The lower portion of the smokebox is reinforced on the inside by a 15 mm. (19/32 in.) plate to withstand damage through corrosion and shovelling. To avoid shovelling out cinders too frequently, a soot blower is provided, the value of which is increased by the exhaust nozzles being very low. In order to allow the cinders to be spread over as large an area as possible and to lower in consequence their level, the smokebox is very long, i.e. 3.15 m. (10 ft. 4 in.). This length is also the result of the steam exhaust pipes having short and direct courses.

Although the exhaust pipes have been duplicated, as is the current practice since Mr. F. LEGEIN took the initiative successfully in 1925 on the old *Pacific* locomotives of the Belgian State Railways, and in order to use correctly two intermediate petticoats, the value of which he has fully shown [1], the level of the two blast pipes was still reduced further than usual. On the new *Atlantic* locomotive this level is only 190 mm. (7 1/2 in.) above the bottom of the smokebox and is, on the other hand, 1.825 m. (5 ft. 11 55/64 in.) below the top of the chimney owing to the gauge which is limited to 4.28 m. (14 ft. 1/2 in.). This American double petticoat arrangement is only practicable when there is great free height. Each of the blast pipes is 113 mm. (4 7/16 in.) diameter, the

[1] Cf. *Bulletin of the International Railway Congress Association*, June 1920.

first petticoat above them being 190 mm. (7 1/2 in.) and the second 320 mm. (12 9/16 in.) diameter.

The accurate coincidence of the vertical centre line of the blast pipes, petticoats and chimney pipes being of prime importance, all these details have been machine-bored. The respective levels of these details being also important, they have been made dependent upon each other by a very rigid framing which cannot be mounted except in the correct position.

The results have been most satisfactory as can be seen on the diagram, Fig. 3, of the vacua shown in millimetres of water in the smokebox, in terms of the exhaust counterpressure shown in kgr./cm² and recorded in accordance with the arrangements used on the French Railways.

Furthermore, it became apparent at the outset that, under all conditions, the boiler easily produced the steam used by the engine up to combustion rates of approximately 600 kgr./m² (122 lb./sq. ft.) of grate area per hour. The combustion has not been pushed further, not only because the engine could not be overloaded, but also with the object of avoiding a possible cause of deterioration of the copper inner firebox.

It has been ascertained, however, during periods of fast acceleration, that the highest rates of combustion could easily be sustained.

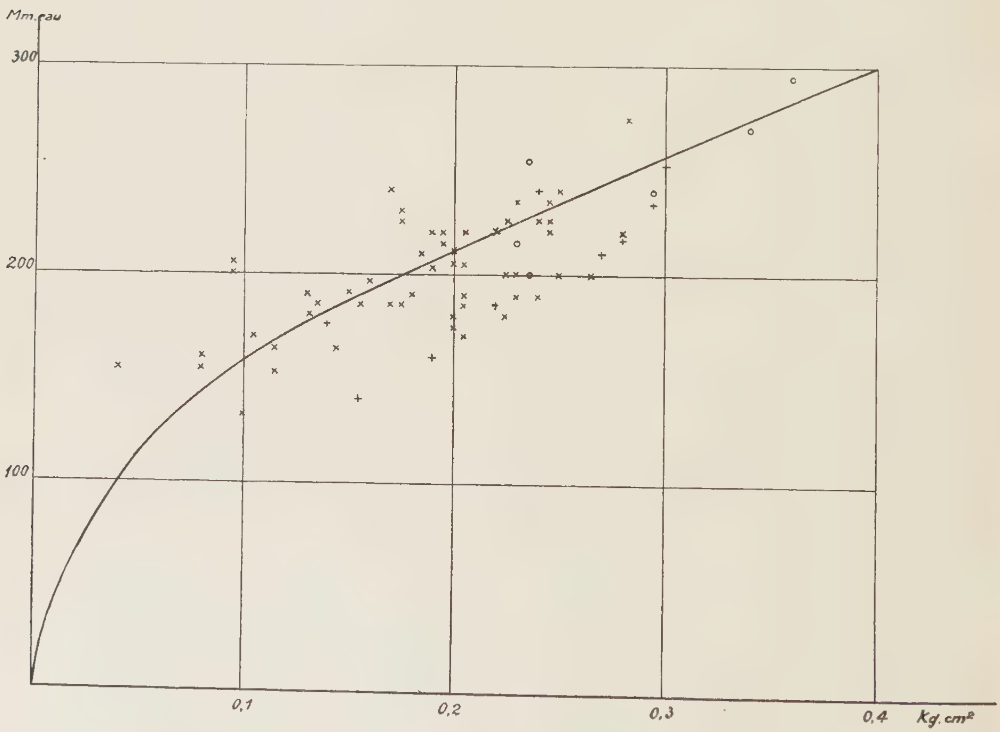


Fig. 3.

(To be continued.)

[625 .23]

Reduction of noise in railway rolling stock (*),

by Messrs. BANCELIN,

Principal Engineer in charge of the technical management of the laboratories, French National Railways Company,

and RENAULT,

Inspector, carriage and wagon testing section, French National Railways Company.

(*Revue Générale des Chemins de fer.*)

SECOND PART.

LABORATORY INVESTIGATIONS.

(Continued.)

3. *Single partition, having one face covered with some light material.* — The readings taken with a sheet so treated show that the amplitude of vibration at resonant frequencies diminishes and consequently that the effect of the light material is to increase the damping co-efficient of the sheet of metal.

In formula (3), if s increases R does so too, which experiment confirms. At resonant frequency especially, it is possible to determine, from (3*a*), the new damping co-efficients of the partition. In the case of a sheet covered with pulverised textile material (1) (see Fig. 8) we have :—

Sheet 1 mm. (0.039") thick, $R'_1 = 18$ dbl;
$s'_1 = 600$, and $s'_1 - s_1 = 445$;
Sheet 2 mm. (0.078") thick, $R'_2 = 2$ dbl;
$s'_2 = 775$, and $s'_2 - s_2 = 430$.

The difference between the damping co-efficients of the two partitions is thus nearly constant, whatever the weight, provided the latter be small. If the partition is very heavy its damping co-efficient is large and the difference $s' - s$ will then be small with respect to s, and R will then be nearly the same in the two cases.

A light material affixed to a very heavy partition has consequently no effect on the transmission of sound through it.

4. *Double partition formed of two plain walls, the inner faces of which are covered with a light thin material.* — The material, being light and thin, possesses little power of absorption and serves principally to damp the vibrations of the partition.

(*a*) If the case is considered where the air space is nil, that is to say the two plain walls are secured to each other through some light material, such a partition can itself be regarded as thin and as the damping co-efficient s increases, R does so too, according to Formula (3). A so-called « biflock » sheet (1) is much superior to a plain treated sheet; the increase in the damping co-efficient is double ($s'_1 - s_1 = 910$ instead of 445 as given in Paragraph 3).

(*b*) When the air space assumes a finite value and it is desired to take into consideration the damping values s_1 and s_2 of the two walls, the problem is more difficult to solve. However, at the fundamental resonant frequency, R assumes the value :

$$R = 20 \log \left[\frac{s_1 + s_2}{2 \rho c}\right] \text{ (Fig. 9).} \qquad (5)$$

(*) Concluded from page 31, January 1940 number.

(1) The « flock » process.

(1) A « biflock » sheet is composed of two metal sheets of different thickness, secured to each other by pulverised textile material, or « flock ».

Knowing s_1 and s_2, R can be deduced from them. For steel sheeting in particular, Formula (4) gives 15 dbl, whereas 14 dbl are obtained by experiment, and for sheets covered by pulverised textile material it gives 24.5 dbl instead of 25.5 dbl, a sufficiently acceptable approximation.

Double partition in which the space is filled by some insulating material.

When the porosity and the acoustic resistance of materials are known it is possible to determine, by the quadripole method, the diminution in sound produced by walls made of them, but these characteristics are very difficult to ascertain and its measurement by experiment has to suffice. In all the experiments the material completely filled up the space between the walls; the results of the readings are shown in Fig. 10.

It will be noticed that if the space between two thin walls is completely filled by certain materials, the advantage gained is much less than would have been expected; nevertheless numerous suppliers of materials incorrectly designated as sound-resisting assert that the packing of such a space with them gives excellent results.

(b) **Transmission of sound through windows.**

The theory of the single and double partition is applicable to single and double windows; Formulas (1) and (4) only serve indeed to give an idea of the degree of approximation to be expected of them with respect to experimental results.

Test equipment. — The partition dividing the chambers in the « silent » room is formed of a double metal wall having high sound insulating properties. An opening is formed in it, measuring 1 m. × 0.800 m. (3' 3 3/8" × 2' 7 1/2"), in which the glass panes to be tested are mounted by being bolted down tight in the wooden frame (Fig. 11). The measuring method is the same as that adopted for metal partitions; however, only two points were selected for taking the measurements and, in place of ordinary reading off, it was thought advisable to adopt sound recording when determining the resonant frequencies. The heterodyne emits a sound the frequency of which varies continuously and an electro-mechanical pointer hand gives an exact indication of the frequencies.

Experimental results.

1. *Single window glasses.* — It is found that the curves obtained in practice for light-weight window glasses are fairly near the theoretical ones given by Formula (1), and at outside frequencies the practical curve is removed from the theoretical one in proportion as the glass is heavier (1).

2. *Double window glasses.* — Experiments have been conducted:

(*a*) on glasses of the same material and weight;

(*b*) on glasses of different weights.

Double glasses of the same material and weight. — Formula (4) may be written as :—

$$R = 10 \log_{10} \left[1 + \frac{\sigma^2 \omega^2}{\rho^2 c^2} \left(\cos \frac{\omega d}{c} - \right.\right.$$
$$\left.\left. - \frac{\sigma \omega}{\rho c} \sin \frac{\omega d}{c}\right)^2\right]. \qquad (4a$$

For small values of ω, R is equal to that of a single glass of weight 2σ, then passes through a series of maxima for the values of ω satisfying the equation :

$$\tan \varepsilon r \frac{d}{c} = \frac{1}{\omega_r} \cdot \frac{2 \rho c}{\sigma}.$$

Figure 8 summarises the results of exper-

(1) Weights of the various single glasses used :

Plexiglass 2 mm. *(0.078")*	2.2 kgr./m²	*(0.45 lb./sq. ft.).*
Plexiglass 4 mm. *(0.156")*	4.4 kgr./m²	*(0.9 lb./sq. ft.).*
Triplex	11.25 kgr./m²	*(2.3 lb./sq. ft.).*
Securit	13.7 kgr./m²	*(2.8 lb./sq. ft.).*
Katathermic	13.75 kgr./m²	*(2.82 lb./sq. ft.).*
Bitriplex	17.8 kgr./m²	*(3.6 lb./sq. ft.).*

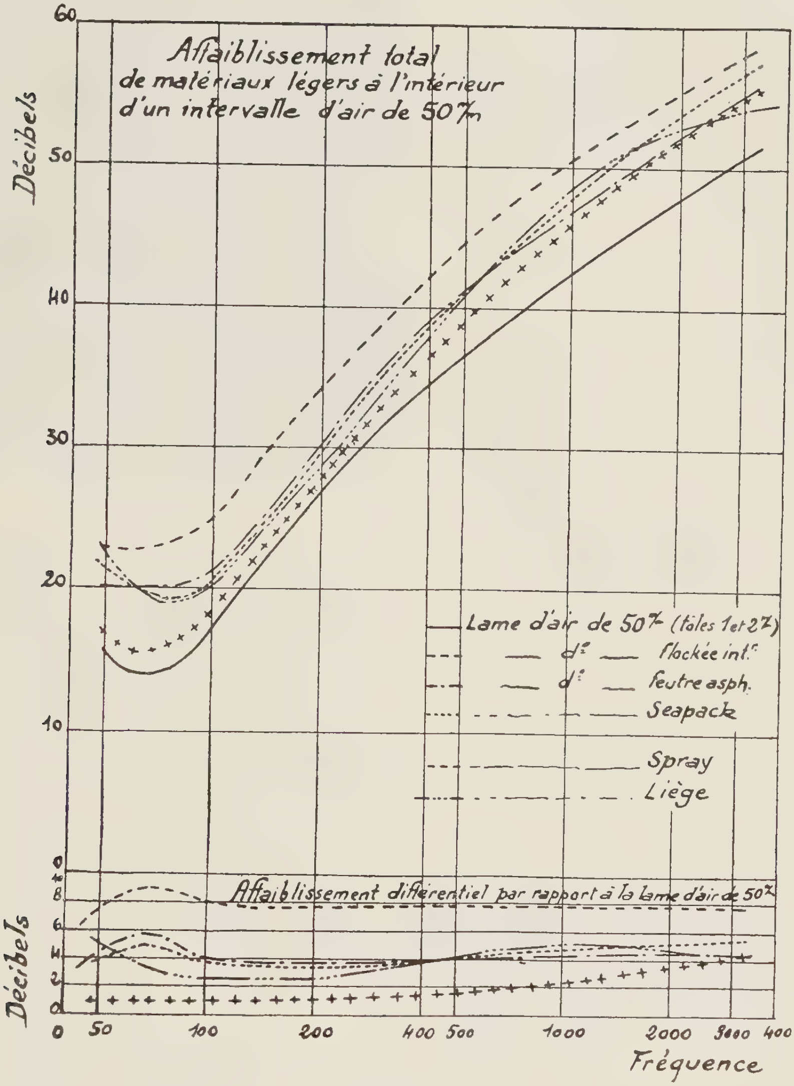


Fig. 9.

Explanation of French terms:

Affaiblissement total... = total diminution with light-weight materials inside an air space of 50 mm. (2 in.).

- air space of 50 mm (2 in.), 1 and 2-mm. (0.039 and 0.078 in.) plates.
- air space filled with slag wool, 50 mm. (2 in.).
- air space flock treated.
- air space, asphalted felt.
- air space seapack treated.
- air space spray treated.
- air space, cork.

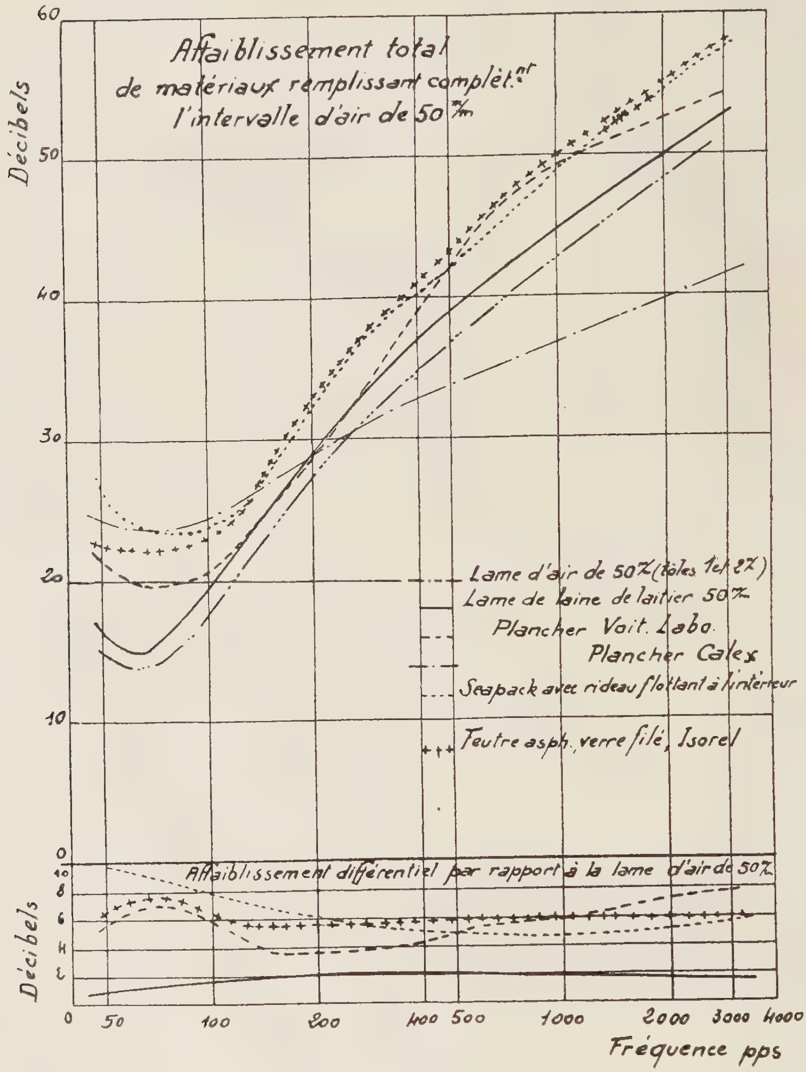


Fig. 10.

Explanation of French terms:

Affaiblissement total... = total diminution with materials completely filling the 50-mm. (2 in.) air space. — Affaiblissement différentiel... = differential diminution with respect to the 50-mm. air space.

—·——	50-mm. air space (1 and 2-mm. plates).	——·——	Calex floor.
————	Slag wool packing in 50-mm. space.	- - -	Seapack with floating curtain inside.
— — —	Floor of test carriage.	+ + +	Asphalted felt, spun glass, Isorel.

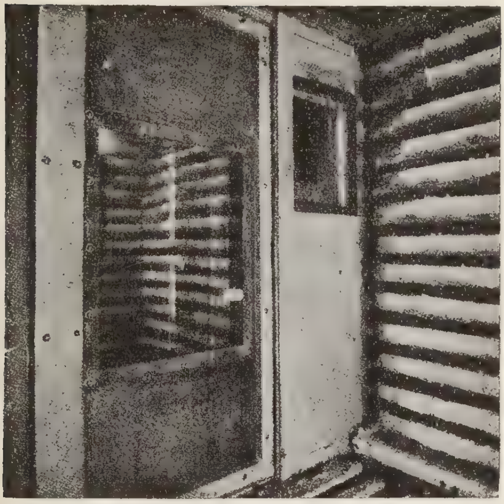


Fig. 11.

iments made on light-weight glass — up to 200 p.p.s.; the diminution attained in practice only differs by from 4 to 6 dbl from the maximum theoretical amount, but this difference unfortunately increases for the higher frequencies and the heavier glasses.

Double glass of different weights. — Combinations involving heavy-weight glasses only present no practical interest, and the tests were restricted to windows of one heavy and one light-weight glass. A close agreement is found between theory and practical experience at low frequencies and for light glasses, and the divergence becomes greater in proportion as the frequency increases and the glass becomes heavier.

This investigation shows that :

1. There is no advantage in fitting very heavy single glass, the increasing weight bringing no marked advantage in sound insulating qualities;

2. Light-weight double glass, spaced 5 to 6 cm. (2" to 2 3/8") apart, possesses insulating qualities greater than a single glass of equal weight.

(c) Influence of openings.

We have seen that it was necessary to make sure, before taking any readings, that a partition is perfectly tight; actually if *f* is the area of a crack or opening in a compartment, the area of which is S, the diminution of the sound R' due to such partition is given by :

$$R' = R - 10 \log \left(1 + \frac{f}{k\,S}\, 10^{-\frac{R}{10}}\right)$$

R being the diminution when there is no opening at all, and *k* a constant.

Therefore, if *f* increases R becomes smaller, and as R is very large at high frequencies R' will fall the more as the frequency rises. This is confirmed by experiments.

II. — TRANSMISSION THROUGH SOLIDS.

The noise transmitted through solid materials can arise from :

(*a*) the shocks caused by the tyres passing over rail joints;

(*b*) vibrations induced by the passage of the vehicle along the rail.

Noise due to shocks.

The shocks of the wheels at the rail joints are transmitted by the framing of the vehicle to the wall and partition plates, which resound like real diaphragms; the metal sheet starts to vibrate as if it received the shocks directly. To reduce the amplitude of these vibrations special materials are affixed to the sheet metal. The problem of how to measure the efficacy of these materials therefore arose and the method of doing it consisted in striking the plate with some mass in exactly reproducible conditions and then ascertaining the time the emitted sound lasted.

The test panel is the same as that used to measure the diminution of sound by trans-

Fig. 12.

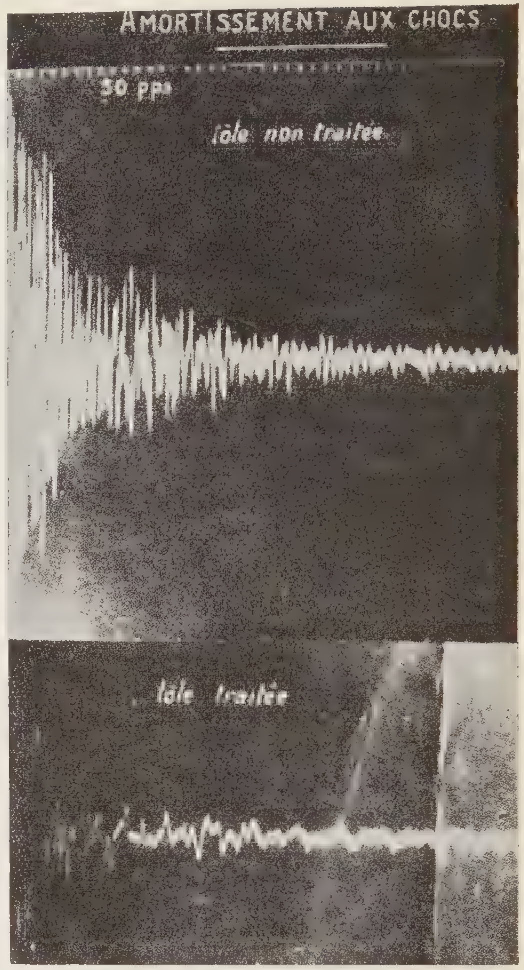


Fig. 13.

Note. — Amortissement... = absorption of shocks. — Tôle non traitée = non treated plate. — Tôle traitée = treated plate.

mission :— a pendulum attached to a balance lever (Fig. 12), always falling from the same height, is made to strike the centre of the panel; the microphone of the sonometer, placed 1 m. (3' 3 3/8") behind the panel, records the resultant noise as an oscillograph. In this manner the time can be determined, necessary for the vibration to die out at 1/1000th of its original amplitude; this time is called the « vibration attenuation period » (1). It thus corresponds to a fall of 60 dbl. In actual practice, as the apparatus only permits of measuring a fall of 20 dbl, the third of this time only is measured, the curve of attenuation being assumed to be logarithmic.

With single plates, for example, the following results (Fig. 13) were obtained :

(1) A definition analagous to that of the re-echoing period in the acoustics of rooms.

Lined materials.	Bare plate.	Pulverized textile material, 1.5 mm. *(0.058")*	« Biflock »	Seapack, 5 mm. *(3/16")*	Cork, 10 mm. *(3/8")*
Plate of 1 mm. *(0.039")* .	1.5	1	0.6	0.8	0.8
Plate of 2 mm. *(0.078")* .	1.4	1.2	—	1.1	1.1

Vibrations.

The transmission of vibrations can be attenuated by making as great a break as possible by means of vibration absorbing material, between the running gear and the body of the carriage.

To measure the efficacy of this material an electric motor, fitted with an eccentric weight, was mounted on a vibrating platform 2.24 m. × 1.00 m. (7' 4 3/16" × 3' 3 3/8"). The measuring method adopted was to interpose the material just mentioned between the platform and the ground and record by means of a vibrograph the amplitude of the vibration when the platform rested directly on the ground and when the insulating material was interposed.

The co-efficient of transmission ρ is defined as the ratio of the amplitudes of the movements. It is shown that :—

$$\rho = \frac{1}{\left(1 - \frac{\omega^2}{\omega_0^2}\right)} \quad . \quad . \quad . \quad (6)$$

where ω_0 is the natural pulsation of the material and ω that of the plaform. In practice friction always exists tending to diminish ρ, but it is nonetheless true that while $\frac{\omega}{\omega_0} < 2$, ρ is not very small.

ω_0 can be calculated when E, the modulus of elasticity of the material, p the unit pressure, and e its thickness, are known :—

$$\omega_0 = \sqrt{\frac{E}{pe}} \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Thus, to obtain a good insulation effect ω_0 must be kept as small as possible, that is to say :—

(*a*) the unit pressure p must be high (although a limit is then set by the risk of permanent deformation);

(*b*) E should be as small as possible;

(*c*) e has to be large.

Formula (6) shows that the insulation becomes the more difficult to obtain the lower the frequency of the vibration; readings should therefore be taken in the most unfavourable case, a very low frequency being considered.

The following table shows the results obtained with different materials (Fig. 14).

—	Thickness.	Test frequency in p. p. s.	Pressure in kgr./cm² *(lb./sq. in.)*.	Amplitude of vibration in mm.	Co-efficient of transmission.
Vibrating floor alone . .	0	14	33 *(469)*	0.06	1
Floating floor	22	14	33 *(469)*	0.03	0.5
Floating floor	22	14	75 *(1 066)*	0.04	0.6
Asbestos emulsion . . .	40	14	33 *(469)*	0.01	0.2

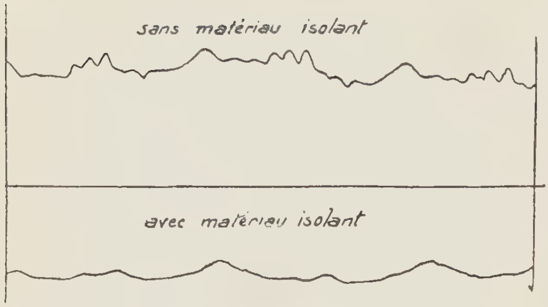


Fig. 14. — Amplitude of the vibrations.

Note. — Sans (avec) matériau isolant = without (with) insulating material.

Conclusion.

It follows from this laboratory investigation that :

(*a*) the diminution of sound produced by a thin homogeneous partition or a single sheet of glass is first and foremost determined, for a given frequency, by its mass;

(*b*) for a double partition or double sheet of glass it is advantageous to use light-weight elements spaced 5 to 6 cm. (2" to 2 3/8") apart; the effect becomes noticeable starting from 300 to 400 p. p. s.;

(*c*) the diminution of the sound increases markedly if some light material is affixed to the thin partition;

(*d*) filling the space between a double partition with an « insulating » material is not very efficacious;

(*e*) generally speaking, partitions which have a high power of diminution at the fundamental resonant frequency possess a short vibration attenuation period.

(*f*) the thick materials transmit vibrations but little.

THIRD PART.

PRACTICAL TESTS AND RESULTS.

Before giving a sketch of the results obtained up to the present it appears necessary to recall the general principles governing sound-proofing.

The investigation into the proper acoustic arrangement of a vehicle is guided by the following principles :

— to reduce above all the loudest noises, in accordance with the law of superposition and possible masking effects;

— to attack the actual sources of the noises;

— to stop, or at least diminish, their transmission;

— to absorb the residual noise.

Now the sources of noise in rolling stock comprise :

1. Sources outside the carriage body.

The principal source of this kind is the shock produced by the wheels at rail joints, then come the small ones between the wheel treads and the many inequalities of the rail, and of the wheel flanges against the rail, the noise from the axle boxes moving in their guides, the sliding of the journals in their bearings, the grating and grinding of badly lubricated parts, such as pivots and guides of bogies, rattling of brake rigging, and the noise from the dynamo and possibly from the air conditioning ventilator. These are so many outside sources of noise needing to be tackled vigorously, without forgetting also the noise, aerodynamic in origin, produced at high speeds by the friction of the air on the outer walls of the vehicle.

2. Sources inside the carriage body.

The internal noises are generally produced by the vibration of the different accessory fittings provided in the compartments : doors into corridor, windows, luggage racks, ash trays, notice boards, etc. To reduce these noises better design and construction must be resorted to.

The transmission of noise coming

from these different sources can be effected in different ways :

(*a*) transmission through the solid framework to the walls of the vehicle, which act as auxiliary sources;

(*b*) transmission through the air, either directly to the atmosphere in the compartment, or to the walls, which act as auxiliary sources.

(*a*) *Transmission through solids.* — To stop this it is necessary to determine its path from the source and set up breaks in the line of propagation, formed of absorbent materials. For example : elastic wheels, rubber blocks between bogie pivot and coach body, insulating material round fixing bolts, sheeting fixed elastically to the framework, etc.

(*b*) *Transmission through the air.* — This has to be prevented as far as possible and is feasible by :

1. Hermetically sealing every opening in the body, which at once raises the question of air conditioning;

2. Absorbing the residual noise inside the carriage body by creating a very absorbent surface and, in certain particular cases, by absorbing the noise before it gets into the body (in tunnels, for example, by covering their walls with absorbent material).

The same principles will be applied to the diminishing of the rustling noise of conditioned air, either by providing large absorbent surfaces inside the ducts or by installing acoustic filters.

In order to be able to measure exactly the effects of the application of these principles, it appeared indispensable to investigate the noise obtaining in different vehicles running under particular conditions. From this certain observations were drawn, very useful in investigating the question of soundproofing.

Influence of speed.

The noise from rolling stock in motion

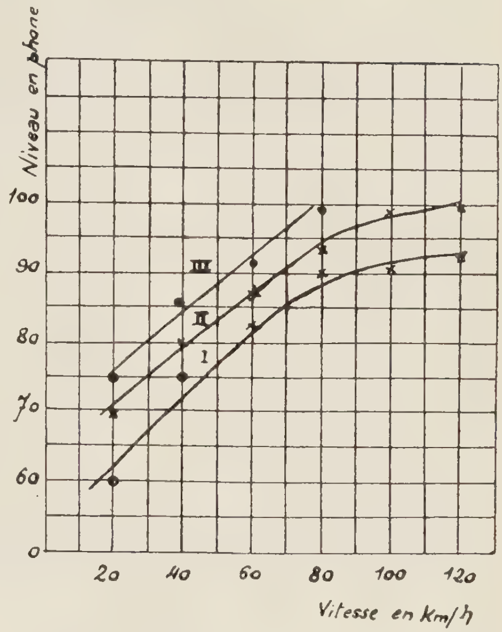


Fig. 15. — Noise level in terms of the speed.

I. = All-metal O C E M, C 10 carriage.
II. = Bugatti railcar.
III. = Electric motor coach, Class No. 3.

Note. — Niveau... = level in phons. — Vitesse... = speed in km./h.

increases with the speed and the increase varies with the class of stock : carriage, railcar or motor coach. Figure 15 shows the noise level in terms of the speed. The noise increases rapidly up to a speed of 80 km. (50 miles) per hour and assumes less importance at higher speeds.

Influence of noise sources.

The levels of certain noise sources are shown in the following table. The readings were taken in an O. C. E. M. carriage, of C 10yfi type.

Influence of transmission through air.

The importance of the transmission of noise through air is easily shown by opening the windows.

Nature of the source of noise.	Speed of vehicle in km./h. *(m. p. h.)*.	Place where reading was taken. (Compt. number).	Mean height of noise level with respect to the normal level on the *subjective method*, in phons.	Remarks.
Heavy rattling of brake rigging.	80 *(50)*	5	4 to 6	...
Lighting dynamo.	30 *(18.6)*	2 above the dynamo.	4 to 6	Above 40 km. (25 miles) the noise of the dynamo is masked by other louder noises.
Emergency brake application.	90 *(56)*	1	6	Brake application lasting 10 seconds; the objective method records 6 to 8 dbl. in the frequency bands 320 to 640 p. p. s.
Rattling of sliding door.	80 *(50)*	5	2 to 4	...

In the tables below the effect of such transmission, measured in a C^{10} type carriage, is set out.

Conditions in which readings were taken.	Mean height of noise level with respect to the normal level on the *subjective method*, in phons.	Remarks.
Window open.	4 to 6	6 to 8 phons in a carriage running through a cutting.
Doors open into corridor.	4	...

Conditions in which readings were taken.	Diminution of noise level with respect to the normal level on the *subjective method*, in phons.
Internal obturation of window frame.	2 to 3
Asbestos packing filling holes through which heating piping passes.	4

Influence of transmission through solids.

The difference in the noise level in a carriage having a wooden body and an all-steel one enables the sound conductibility of solids to be appreciated. As the following table shows, wood conducts noise less than steel. (See p. 55.)

Influence of re-echoing.

Sound vibrations, being propagated inside a compartment, encounter the partitions again and are reflected therefrom a great many times a second. They die out all the more rapidly as the absorbent power of the walls and floor is greater. This explains why a 1st-class compartment is always less noisy than

Type of vehicle.	Noise level, in phons, Compartment No. 1.	Noise level, in phons, Compartment No. 5.	Difference between the two compartments.
Metal coach, B9	92	88	4
Coach with wooden body with outside metal sheet covering A3 B5	92	84	8
Difference, in phons, between these coaches.	0	4	...

any other and the corridor always noisier than a compartment.

Influence of running.

Carriages all having substantially the same running gear, railcars alone can give an idea of the noises produced by running : the mean noise level in a 36-seater « Micheline » fitted with pneumatic tyres as a matter of fact only attains 70 phons, while that of a trailer of a triple « Renault » railcar, not sound-proofed, reaches 100 phons at 120 km. (75 miles) an hour.

Influence of the permanent way and atmospheric conditions.

To judge by the variation in noise noticed when passing stations or bridges, the nature of the track and the surrounding obstacles play a very important part; some readings taken in connection with this matter are reproduced in the following table.

It would appear as if atmospheric conditions affected the measuring of the noise; but a noticeable diminution in the noise (2 to 4 phons) was only observed when the track was covered with fresh snow.

Experiments with sound proofing made on different vehicles. — The first attempts at sound-proofing of rolling stock were made by the Alsace-Lorraine Railways with A8 type carriages, built in 1932. They consist of very simple modifications :—

1. to the bogies;
2. to the body.

In application of the principle of making a break in the path of sound transmission through solids, rubber shock absorbers have been placed under the helical springs on the bogie.

In addition the interior faces of inside and outside body panels are covered with « Feutrisol »; the floor, made of terrazolith,

Nature of the track or adjacent obstacles.	Mean height of noise level with respect to the normal level on the *subjective method*, in phons.	Remarks.
Chaired track.	2 to 4	...
Steel sleepered track.	4 to 6	...
On an embankment.	2 to 4	...
In a cutting.	6 to 8	...
In a tunnel.	12 to 16	...
On a steel viaduct.	6 to 8	...
Roadbed resting on a rocky sub-soil.	10 to 14	Noise resembling a violent wind.

is covered with an under carpet of « Rubber-crin » and a moquette to absorb noise and stop vibration of the panel plates; the latter are covered with thick cardboard, fastened to their surface, either directly or with swan-skin between.

Particular attention was paid to the tightness of the window equipment. Unfortunately the tare of the carriage has been increased by 500 kgr. (1 100 lb.).

The Nord Company in 1935 made a special point of trying to prevent noise passing through the floor. After numerous trials it fitted up an A^8 type carriage with four different floorings of its own design, taking care to stop up all the holes or cracks in the 4 compartments. Figure 16 shows a cross section of these 4 floorings. Nos. 3 and 4 would appear to have made possible a weight saving of some 400 kgr. (880 lb.) as compared with the normal flooring.

In order to verify in actual service the results obtained in the laboratory, the State Railways fitted up two carriages. The first experiment was made on an electric trailer coach, the terrazolith flooring in which was replaced by a floating one formed of a main under plate covered with pulverised textile material and rubber bands supporting a plywood counter floor, the inner walls being treated by a flock process. This experiment proving satisfactory (1) designs were got out for acoustic equipment for a carriage called « the noise test laboratory ».

This vehicle allowed of :

— noises being analysed;

— the different sound proofing processes being studied and the influence of the permanent way being investigated.

This carriage, of the O.C.E.M. C⁹yfi type, having the advantage that the compartment partitions could be easily taken down, was modified in the following manner :

1. *Bogies.* — (*a*) *Wheels.* — The holes in

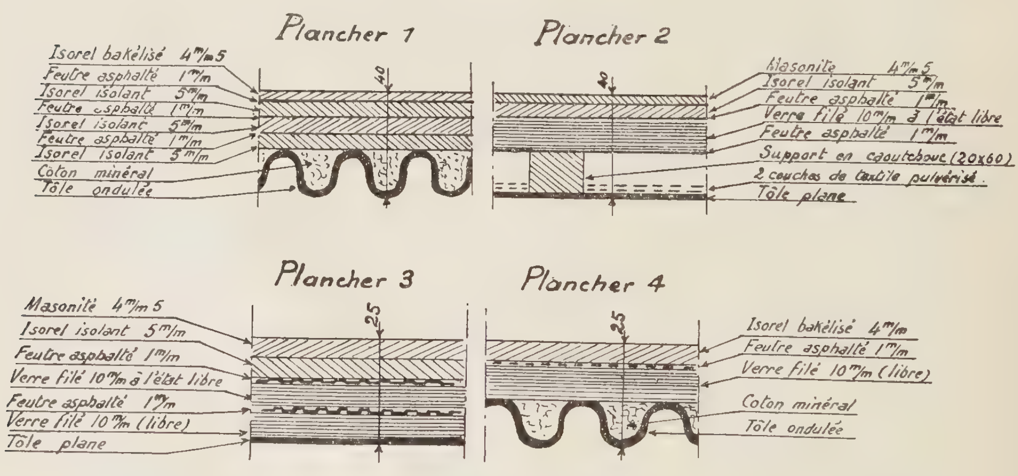


Fig. 16.

Explanation of French terms:

Plancher = floor. — Isorel bakélisé = bakelised Isorel. — Feutre asphalté = asphalted felt. — Isorel isolant = insulating Isorel. — Coton minéral = rock wool. — Tôle ondulée = corrugated plate. — Verre filé = spun glass. — A l'état libre = in free state (not fixed). — Tôle plane = flat plate. — Support en caoutchouc = rubber support. — 2 couches... = 2 layers of pulverized textile material.

(1) Average improvement of 6 to 8 phons.

I. — *BOGIE.*

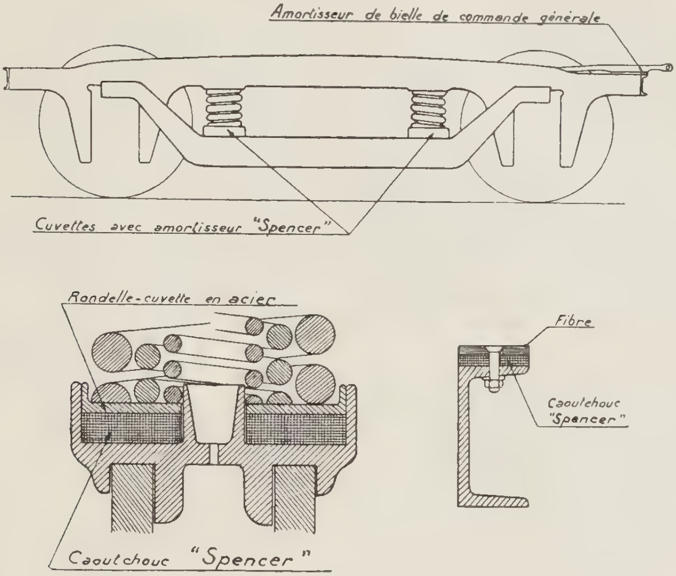


Fig. 17.

Note. — Lubrication of the box flanges, side friction blocks, rubbing plates and pivot is on the « Tecalemit » system, fed by a shaking type pump attached to the bogie main frame. The dynamo is mounted on the bogie and is suspended on « oscillit ».

Explanation of French terms:

Amortisseur... = shock absorber on brake lever coupling. — Cuvette avec... = spring cups with Spencer shock absorbers. — Rondelle-cuvette... = cup-shaped steel washer. — Caoutchouc Spencer = Spencer rubber.

each wheel centre were blocked up by two pieces of lead held together by a bolt and two disc plates, without contact with the wheel.

(*b*) *Frame.* — To eliminate grating of the bogie centre, side friction plates and axle box guides, pressure grease lubrication was fitted, using the « shaking » type pump. In addition, armoured rubber was inserted between the swing bolsters and the helical springs, and rubber covered with fibre between the brake rigging and the headstocks (Fig. 17); to ensure a better mechanical insulation of the dynamo, the latter was mounted on the bogie with the « Oscillit » style of fixing.

2. *Body.* — The body was rendered generally sound-proof, and in addition, the four compartments bearing even numbers were treated on different processes.

General sound proofing. — (*a*) *Outside portion.* — The connection between body and bogie is broken by the interposition, in the path of transmission of sound through solids, of armoured rubber between the bogie pivot and bogie bolster, as well as between the latter and the rubbing plates.

To prevent the braking noise being transmitted to the body by the rigging, the brake equipment is insulated from the body (except for the auxiliary reservoir and triple valve) (see Fig. 18). To obtain good insulation of the body from the point of view of transmission through the air, a double floor was fitted, formed of a steel plate covered by pulverised textile material and fixed to the cross bearers, longitudinals and sole bars, already treated with flock, and to an aluminium sheet, similarly treated, fixed on brackets. These plates are 50 mm. (2")

apart, a distance determined on in the laboratory. The least little hole was stopped up by a special plastic material.

(b) *Inside portion.* — After removing all the internal panelling of the carriage, the inside faces of the outer and inner sheeting received two coats of flock. The floor, properly so called, was formed of sheet steel, with rubber strip on which « Masonite » rests, the space between the rubber strips being filled with a mattress of spun glass covered in asphalt-treated felt. The « Masonite » nowhere comes in contact with a partition.

Treatment of the odd numbered compartments and the corridor. — Ordinary window glass was replaced by Securit glass panes, plain and balanced, the imperviousness of which to noise has been specially studied. The blind guides, on the corridor side, are treated with felt to eliminate vibration of the wire ropes; the lower parts of the sliding doors were fitted with noiseless guides and a special fitting of felt rendered their edging perfectly tight. The steam radiators rested on the floor through rubber strips and all the deflectors were fitted with « Akousticos » felt, so creating a supplementary and very absorbent surface near the floor.

Finally, it must be remembered that the fitting out of the compartment was retained in its original form.

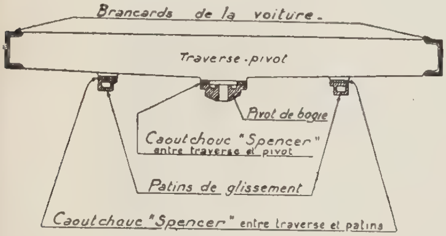
In the lavatories, the panel sheeting was replaced by « biflock » and the floor plating simply covered with a rubber mat. The hopper is of the trap type with pedal action.

Sound proofing of the even numbered compartments. — Apart from the general sound-proofing measures described above, each even numbered compartment was equipped as in the following table.

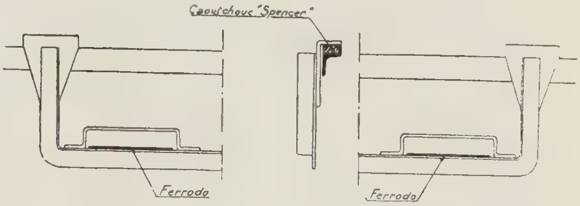
No. of compartment.	Floor.	Partitions.	Side.	Roof.	Remarks.
2	Hard « Masonite ». Asphalted felt. Spun glass. Asphalted felt. Spun glass.	Double floating partition.	Spun glass stuck on.	Spun glass stuck on.	Compartment covered with a layer of anti-vibration paint. Compartment designed to reduce low-frequency noises.
4	Perforated aluminium. « Plymax ». Rubber backing. Floating « Seapak ».	« Biflok » plate.	Stuck on « Seapak » and floating « Seapak ».	Stuck on « Seapak » and floating « Seapak ». Roof plate perforated.	Double fixed « Plexiglas » window. Designed to reduce high-frequency noises.
6	Hard « Masonite ». Rubber strip.	Visible flock process.	Visible flock process. « Isoflex » in air space.	Visible flock process. « Isoflex » in air space.	Compartment designed to absorb residual noise.
8	Hard « Isorel ». Asphalted felt. Insulating « Isorel ». Asphalted felt. Insulating « Isorel ».	Chequered plating.	Spray.	Spray.	...

II. — *BODY.*

1. *Connection between body and frame.*
Application of « Spencer » rubber fittings.

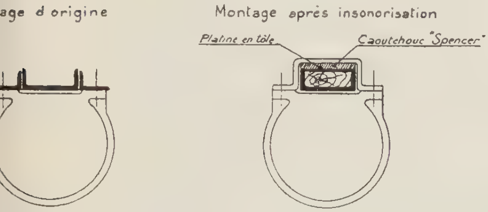


(*b*) *Mounting of the horizontal equalizer supports.*



2. *Mounting of brake gear on « Spencer » rubber fittings.*

(*a*) *Cylinder.*



(*c*) *Mounting of the roller supports.*

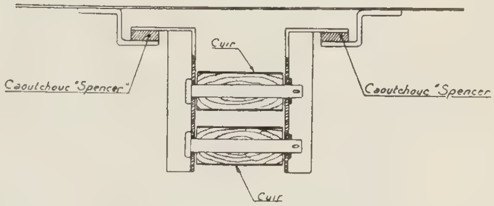


Fig. 18.

Explanation of French terms:

Brancards... = sole bars of the carriage. — Traverse-pivot = bogie bolster. — Pivot de bogie = bogie pivot. — Caoutchouc Spencer... = Spencer rubber fitting between bogie bolster and pivot. — Entre traverse et patin = between bogie bolster and rubbing plate. — Montage d'origine = before sound-proofing. — Montage après insonorisation = after sound-proofing. — Platine en tôle = metal plate. — Cuir = leather.

These modifications increased the weight of this carriage by 500 kgr. (1 100 lb.) without taking into account the replacement of the Pottier heating equipment by the Westinghouse type, on account of ease of fixing.

More recently the Est System, after having been the first to apply the flock process to its suburban carriages, from 1936 onwards, has applied it also to its most recent main-line carriages, type C^{11} C^{5}, as well as mounting insulating rubber plates on the bogie suspension gear.

The P. L. M. System, in addition to sound-proofing a vehicle by the flock process and rubber shock absorbers, has also treated a C^{11} type carriage on the « Johns-Manville » process.

The framing, composed of the cross bearers, pillars and longitudinals, forms a box padded with « Banroc ».

The « floating » floor is formed of « Plymax » panels fixed on wooden frames, resting on felt insulating pieces by a bottom plate covered with felt and « Airacoustic » panels.

The outer and end walls have their inside faces similarly covered, as well as the inner face of the outer roof sheeting. The ceiling is in perforated plate. The transverse compartment partitions, and longitudinal ones between the compartments and the corridor, are lined above the roof member with felt and « Banacoustic » panelling inserted in perforated plating, and below with felt and « Airacoustic » panelling. The window bays are made tight by rubber tube and strip; double glass is fitted in the windows of the entrance, through communication, and corridor end door. The seats are independent of the partitions, the ventilating ducts fitted

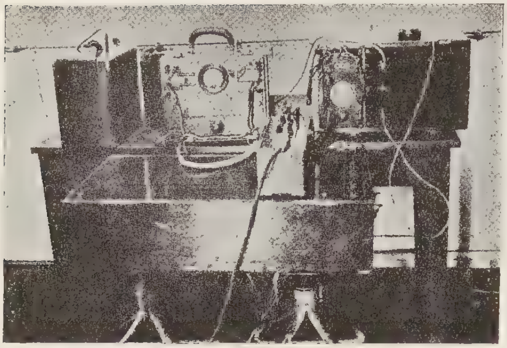


Fig. 19.

with felt inside, the radiator feed pipes being insulated by means of « Durite » sleeving. This sound-proofing equipment has increased the weight of the vehicle by 5 tons.

Practical results.

Measuring the noise met with in rolling stock is only of interest as a comparative process : it is accomplished by two methods :

(*a*) objective;
(*b*) subjective.

Objective method.

The measuring apparatus used is a sonometer, completed by a series of band pass filters (fig. 19). The noise intensity being very variable, recording is adopted. After using an oscillograph to begin with, a recording milliammeter with low time constant [1] was adopted and has given every satisfaction. Figure 20 shows the records made in two carriages during the same run.

Subjective method.

The masking method is used, and reading off is with the aid of the apparatus shown in Fig. 21.

Comparative readings were taken in December 1937, in sound-proofed carriages treated on the different processes already described.

All these carriages showed an appreciable improvement over those of similar type but not treated.

The Nord A^8 carriage gave a gain of 5 to 6 phons, thanks to its special floorings; the P. L. M. (J. Manville) carriage about 8 to 10 phons; the test carriage of the State lines showed more than 20 phons improvement.

At the rear end of the Sud express on the Paris to Tours run, at 130 km. (82.3 miles) an hour, the following minimum sound intensities were found, (each reading given in the table is the mean among 15).

Carriage.	Type.	Compartment.	Mean level, in phons.
Alsace-Lorraine	A^8	d	72
Est	$C^{15}c^5$	f	77
State	C^9	4	58
Nord	A^8	3	68
P. L. M. . . .	C^{11}	6	75
P. O.-Midi . .	A^8	4	72

Minimum sound intensity of a « normal » A^8 carriage being 73 phons, and of a type C carriage, 85 phons.

The test carriage of the State System of lines, although not a completely fitted out vehicle, thus turned out to be the best.

Below are given the results obtained in the four test compartments of this carriage.

(1) The Paris Congress fixed the time constant for sonometers at 0.2 second. The apparatus used by us has one of 0.5 second, which is amply sufficient.

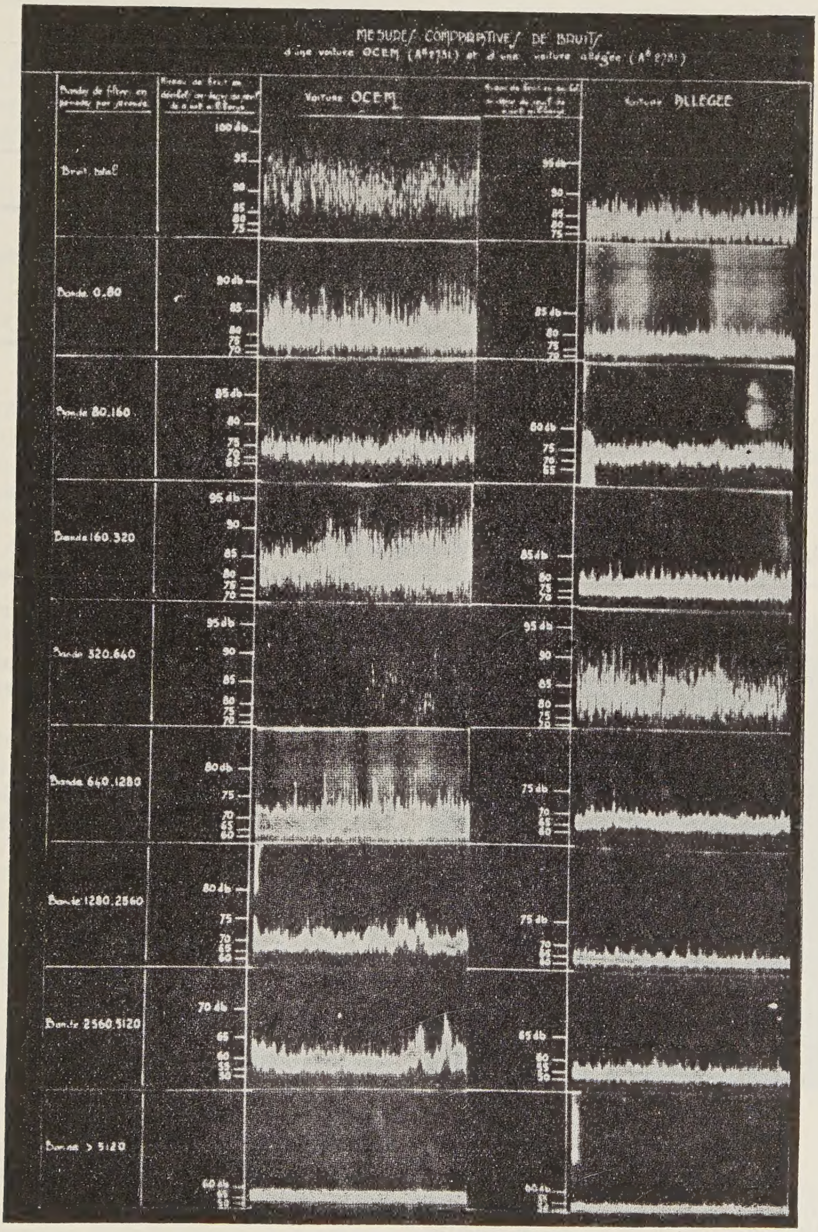


Fig. 20.

Note. — Mesures comparatives... = comparative measurements of noise in an O. C. E. M. carriage and a light-weight carriage (right and left respectively).

Subjective method.

	Compartments			
	No. 2. Floating partitions.	No. 4. Perforated roof. Floating floor.	No. 6. Flock process.	No. 8. Chequered plating.
Level in phons . .	70	58	64	71

Objective method.

Compartments	Mean readings, in decibels.			
	No. 2.	No. 4.	No. 6.	No. 8.
Total noise	69	65	67	70
Band 0-80	59	60	60	59
Band 80-160	55	52	52	56
Band 160-320	57	57	58	57
Band 320-640	64	60	63	65
Band 640-1280	56	50	51	56
Band 1280-2560	52	47	47	50
Band 2560-5120	41	39	40	42
Level, in phons, according to Fletcher and Munson.	77	74	76	78

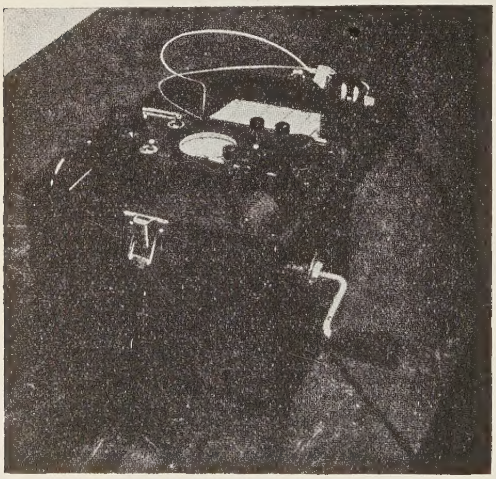


Fig. 21.

Compartment No. 4 is distinctly more silent than all the others; No. 6, thanks to its large absorbent surface, comes immediately after it. Compartments Nos. 2 and 8 are almost alike.

The results of these readings by the two methods lead to similar conclusions :

(*a*) General sound-proofing has permitted of the general sound level being brought down by 20 phons.

(*b*) No. 4 compartment, in which the sound-proofing process was most completely effected, is distinctly the best and the high-frequency sounds have been appreciably reduced in it.

(*c*) The visible flocking of No. 6 allows of a noticeable absorption of residual noises.

(*d*) No. 2 compartment is little different from its fellow No. 8, the sound-proofing of which was not the subject of special study.

The results thus obtained are therefore most satisfactory.

In addition, some subjective readings effected on different types of railcar such as Micheline, Bugatti and Franco-Belge may be given.

At 100 km. (62 miles) an hour, the engines working at full power, the mean sound level (1) was found to be :

Micheline (36 seats). . . . 70 phons

(1) On tracks considered nearly alike.

Bugatti (800 H. P.) (1934) . 98 phons
Franco-Belge (1938 type). . 80 phons

We may recall as a comparison that, as given in the table on the preceding page, a mean level of 72 phons has been obtained in good typical all-steel carriages, such as the Alsace-Lorraine A[8] and the P. O. Midi A[8].

CONCLUSION.

The results of these tests have been given for information purposes only. Numerous systematic experiments are at present being made, especially with the noise investigation test carriage and a carriage on which the bogie pivots are equipped with different kinds of noise absorbers, but the experiments are not sufficiently advanced to be made public.

We hope, however, that the present article will contribute to increase comfort and bring us nearer to the final object, speed with silence.

NEW BOOKS AND PUBLICATIONS.

[625. 14]

BINGMANN (Dr. Ing. W.), Regierungsbaurat im Reichsverkersministerium, Berlin. — **Betrachtungen zur Oberbaustoffwirtschaft unter besonderer Berücksichtigung der wiederholten Verwendung der Gleisstoffe** (*Considerations on the Economics of permanent-way materials from the special viewpoint of their re-use*). — A volume (8 × 5 3/4 inches) of 112 pages, illustrated. — 1939, Otto Elsner, publisher, Berlin S. W., Vienna and Leipzig. (No price stated.)

The high speeds which are now common practice and the increasing axle loads give rise to ever growing stresses in the permanent-way equipment.

Railways have to meet these new requirements as economically as possible.

This question is dealt with in detail in the book just published by Dr. Ing. W. Bingmann.

From the statistics drawn up by the Reichsbahn, it appears that the expenditure on the permanent-way fixed equipment represents 20 % of the total expenditure of the railway, half of this 20 % being for track material supply properly speaking.

If the railways are to fight successfully competition from other methods of transport, it is essential, therefore, to reduce to a strict minimum the cost of the materials, as well as the renewal and maintenance costs, thanks to a rational utilisation of such materials.

Briefly, the solution for a railway system carrying various kinds of traffic consists in drawing up a programme for the re-use of the materials according to the extent they are worn, classifying the tracks according to the importance of the loads to be carried and the speeds run.

These problems are dealt with in a clear and elaborate way by Dr. Ing. W. Bingmann.

The results obtained are expressed by formulæ, while examples illustrate and facilitate comprehension of the opinions set forth by the Author.

J. D.

[656. 23]

MOORMANN (Dr. Jur. Karl), Abteilungspräsident, Reichsbahndirektion, Hamburg. — **Leitfaden für den Verkehrsdienst.** Heft I. **Das Tarifwesen** (*Guide-Book for the Traffic Department*. Vol. I. *Rates*). — A volume (8 × 5 3/4 inches) of 98 pages, illustrated. — 1939, Leipzig; published by the Verkehrswissenschaftliche Lehrmittelgesellschaft m.b.H. (Price : 1.32 RM.)

This work is, for the employee in the traffic department, a guide-book which should facilitate his initiation in the very intricate rates question.

It substantially shows the classification of the rates and the chief provisions contained therein as regards passenger, goods, local, inter-railway and international traffic, as well as combined rates for mixed traffic with other methods of transport, standard rates, exceptional (special) rates, etc.

The different ways in which the rates vary in accordance with the distances and the classes of goods are shown.

The work assumes a practical form in that it recalls the laws and bye-laws governing the matter.

The Author in no way wishes to substitute his work for the documents containing the instructions in force, but recalls them and refers the reader to them whenever his statements make this necessary.

The reader will be made familiar with the discharge of his duties thanks to the numerical tables or abstracts from tariff forms of everyday use, and to examples derived from daily experience, particularly in connection with the calculation of charges, and the apportionment of receipts in cases of inter-railway traffic, etc.

E. M.

[385 (.02 (.4)]

VEREIN MITTELEUROPÄISCHER EISENBAHNVERWALTUNGEN. — **Stationsverzeichnis der Eisenbahnen Europas** (früher Dr. Koch's Stationsverzeichnis) [*List of European Railway Stations* — except Great Britain — (*formerly Dr. Koch's list of stations*)]. — A volume (17 × 7 inches) of XX + 1 050 pages. — 1939, Berlin-Wilmersdorf, Von Barthol & Co., publishers, Prinzregentenstrasse, 53. (Price : 28 RM.)

This is the 52nd edition of the list of stations, published under the patronage of the Union of Central European Railways.

As is known (see notice regarding the 51st edition in the July 1936 Bulletin), the stations are listed in two different ways, in geographical order in the first part, and in alphabetical order in the second. In the latter each station name has a reference number showing its position in the first part (classification by railways). Conventional signs show the kind of traffic dealt with in each station, the equipment available for loading and weighing purposes, its situation relatively to the country, the railway system, the railway line, and the other methods of transport ending at the station in question, etc.

A great many alterations were required to take into account the political changes that took place recently in Central Europe, the redistribution of the railway systems, and the altered spelling of a number of names.

As regards Germany, alterations were made according to the new boundaries of the divisional managements, and the nationalisation of private lines. Similar alterations took place in other European Countries, e. g. in France, where the National Railways Company was formed.

The work is based on official information and has been brought up to date as regards the station equipment.

The appendix deals with road services worked by the railways. In the previous edition, this appendix was drawn up on the same lines as the list of railway stations. It has been deemed preferable to draw up an alphabetical list of « subsidiary establishments served by railway-owned road motor vehicles », showing next to the name of each such place the railway transiting station or stations and the distance to be covered by road.

The new arrangement will make investigations much easier, the more so that the number of such establishments has increased to a considerable extent.

E. M.